MEDINFO-83, van Bemmel/Ball/Wigertz, Editors

MEDICAL DATA ACQUISITION USING AN INTELLIGENT MACHINE
(chairman's paper)

H.R. Warner and P. Haug

Latter Day Saints Hospital,
Dept. of Medical Biophysics and Computing, 325 8th Avenue, Salt Lake City, Utah 84143, U.S.A.

There are two approaches to the design of computer-based systems for providing expert consultation to physicians, and they differ primarily in the way data is acquired. In one approach, the physician sits at the terminal and responds to questions that are posed by the system and then receives advice based solely on deductions made from the data he has entered himself. Examples of this kind of system are Howard Bleich's program for consultation on blood gas and electrolyte problems, the MYCIN project of Shortliffe at Stanford, and the INTERNIST system of Meyers and Popple at Pittsburg. In the other approach, typified by the HELP system, the data used for decision-making and consultation are derived from a variety of sources and stored in a central patient record. Data is entered by paramedical personnel or is acquired directly from instruments in the laboratory or connected to the patient. The doctor is the recipient in this system, not the provider of information.

Neither of these approaches by itself solves the data acquisition problem adequately. No physician will tolerate entering data from a terminal that has come to him from another source (not his own observation) if there is reason to expect that the computer system should have received that information directly or that a paramedical person could have acquired the data just as readily and reliably as he/she. Bleich has shown that indeed this is true by his experience with such a system in a medical care setting. On the other hand, the HELP system has proven useful for practicing physicians in a hospital setting, even without data supplied directly from doctors (ie. history and physical examination), but the set of decisions is definitely restricted without this source of information. That a combination of both approaches to the acquisition of data for decision-making offers the best solution must be apparent to everyone working in the field, and it is the purpose of this paper to describe the design and implementation of such a combination using the HELP system.

A data acquisition scenario: As soon as the patient is admitted to the hospital and comfortably settled in his/her bed, the nurse calls the history program on the bedside terminal. The nurse asks the patient for his/her chief complaint and uses the keyboard to enter a key word(s) which she thinks will describe this symptom. One or more symptoms (complaints, attributes, etc.) will be displayed and the nurse and patient together decide which, if any, of these best describe the patient's primary symptom. When the selection is made, that data is stored in the patient's record and the system then forms some hypotheses to explain this problem in light of whatever else it may "know" about the patient (ie. age, sex, attending physician's specialty, hospital ward, preadmit lab values, admitting diagnosis entered at the time he/she was scheduled for admission). These hypotheses are evaluated by execution of the corresponding HELP sectors (decision modules). If some of the data required to complete the analysis is not yet in the patient's record, a request for these items is generated.

If some of this data can be obtained by questioning the patient, the questions chosen first for presentation are those needed to complete testing the most likely hypothesis. The patient answers each question by pressing a single key and the answers are stored in the patient's record. As the new data is stored, the current hypotheses are again tested and any new hypotheses which use this new data are brought up and considered. Thus, the cycle continues until the patient has been asked for all data he/she could provide that bears on the set of hypotheses "appropriate" to his/her state. In the process of analysing these hypotheses generated by the patient's history, items of information (ie. physical examination data) will usually be encountered which can only be supplied by the physician. A request for these items is stored in a query file (electronic mail), and the physician is presented with these requests when he next signs on the system for this patient. His responses to these queries also represent new data for the file and initiate evaluation of old and new hypotheses, and the cycle of hypotheses-testing, requests for new data, and new hypothesis generation continues.

Several features of this scenario distinguish it from other approaches to the online acquisition of a physicians observations. First, the requests for data are limited to that information needed to test the most likely diagnostic or therapeutic decision. These hypotheses are based not only on other data entered by the physician, but on all relevant information in the patient's file from whatever source. It is our hope that the physician will perceive such an encounter with the terminal as an efficient use of his time and effort. Second, each time a request is generated from the query file and presented to the physician on a terminal, the reason for the request (the underlying hypothesis) is also presented. This feature will hold the physician's interest without adding to the time required by the physician to complete the data entry. Finally, each decision is itself stored in the patient's file as an item of data and thus, can evoke the evaluation of other decisions at a higher level that make use of this data. This assures that, with the entry of each new data item, the system will go as far as its medical knowledge (in the form of decision models or hypotheses) and data in the patient's medical record at that point in time will allow.

The components of the HELP system which permit the kind of scenario described above are:

a) a dictionary of terms which are needed to describe a patient's symptoms, physical findings, test results, diagnoses, and treatments, and the corresponding numerical codes which will be stored in the patient's record to represent these terms. The organization and structure (heirarchy) of the dictionary is designed to facilitate the decision-making process by allowing data to be accessed by general or very specific codes.

b) multiple sources of data from throughout the hospital, such as admitting, emergency room, clinical laboratory, radiology, pharmacy, nursing station, ECG, admission screening, cardiovascular laboratory, pulmonary laboratory, and others. It is important that entry of this data into the system become the sole source of such information since this will not only avoid duplication of effort, but will help to assure the quality of the data if everyone is depending on it (ie. the administration for capturing charges, the medical personnel for decision-making).

c) a patient data file provides a memory for the system. In evaluating a decision algorithm, the patient's data file is first examined for the needed information. Medical information is, for the most part, highly time dependent so each item in the file must be time-labeled to allow analysis of temporal relationships in the decision process. All data in the file is coded for efficiency of storage and retrieval and to prevent ambiguity.

d) a medical knowledge base in the form of decision algorithms provides the basis upon which the system can respond to the user "intelligently." This knowledge base is built of modules (HELP sectors), each of which represents a computer-executable model of a discreet decision process. Modularity makes it possible to build a very complex system consisting of sectors from each medical specialty, and have a specialist responsible for just those modules which reflect his/her expertise. Updating is facilitated as well with this approach. A HELP language provides a natural way for the medical expert to describe his decision-making algorithm in the form of a HELP sector using medical terms and arithmetic and/or conditional statements. This is essential if he/she is to assume responsibility for the decisions and suggestions the system generates for the other physicians and nurses. Tools are available for debugging a sector using real patient data before installing it into the "clinical" knowledge base.

e) a data driver provides the mechanism for "inducing hypotheses" to be evaluated. As each decision module (HELP sector) is created by a medical expert, the data items (ie. chest pain, serum potassium less than 2.4, etc) which should evoke consideration of that decision are identified. This will cause the system driver which stores all data in the patient record to initiate the execution of that sector whenever the data being stored is found in the "data-driver" table.

f) a query file provides the mechanism for requesting information needed by a HELP sector to complete the execution of its algorithm if all the data used by that sector is not available in the patient's record. A HELP sector may "ask" for missing data and specify who should be asked and under what conditions. Such requests result in the dictionary codes for the requested item being stored in the query file along with the identity of the person (ie. attending physician, nurse) to whom the query should be posed, the patient ID, and the hypothesis (sector) being tested. Now, when the doctor, for instance, signs on to the terminal at this patient's bedside, he/she is presented with a display (in English) requesting the needed data and is shown the reason for the request (sector message representing the decision being considered).

The HELP system is currently implemented on a TANDEM non-stop computer system with 6 CPU's, 500 megabytes of disc storage, 250 terminals and printers distributed around a 525 bed general hospital, 13 peripheral computers used for high speed data collection and preprocessing, and the capability of expanding to 16 CPU's. The system performs well for the administrative functions such as admit, discharge, and transfer, for the collection and dissemination of medical information, and for those decision processes that do not require a rapid response (a user waiting at a terminal for the results). However, the compute-power required for the kind of decision-making herein described is so demanding of both CPU cycles and disc accesses that it cannot be provided in a timesharing environment.

The demands on the system are almost openended. Requests by users wishing to review patient data, for instance, increase as the response time of the system improves. But, as more requests are made, the response time increases due to the increasing number of transactions accomplished, and eventually the system is doing almost no useful work and spends all its cycles controlling traffic and swapping programs and buffers back and forth to disc. Then, of course the users get discouraged and leave the terminal, allowing the system to eventually catch up and the response time to improve. Addition of more resources (ie. disc, memory, or CPU) provides but a transient improvement in system response, although more users are served, and the compute and I/O intensive decision activities still don't get the response time to satisfy the user waiting at the bedside.

Recent experiments have been conducted in our laboratory using a dedicated CPU with 1 megabyte of main memory to test whether such a system could succeed in overcoming the limitations of the timeshared system. To accomplish the test it was necessary that each of the files described above reside in main memory as well as all the programs needed to accomplish the physician-interaction scenario. The results of this test clearly show that the required improvement in response time can indeed be obtained in a dedicated machine and we are now in the process of implementing all the necessary processes and files on a single user, microprocessor based system. The cost of the hardware for such a system will soon be in the range where a separate system for each bed will be easy to justify and communication with a central machine for downloading patient data and new medical logic can be done in batch mode.